Software Model for Detecting Power Quality Disturbances

Milan Simic[1], Dragan Živanovic[2], Dragan Denic[3] and Goran Miljkovic[4]
University of Niš, Faculty of Electronic Engineering
Aleksandra Medvedeva 14, 18000 Niš, Serbia
milan.simic@elfak.ni.ac.rs
dragan.zivanovic@elfak.ni.ac.rs
dragan.denic@elfak.ni.ac.rs
goran.miljkovic@elfak.ni.ac.rs

ABSTRACT: *We have developed a software testing tool to find the detection and classification of the power quality disturbances. The program was instituted in the Environment called as LabVIEW. We intended to do verify the performance of the developed tool to find the best software algorithm for power disturbances. During the power distribution networks, every real condition is simulated to find the standard power disturbances. We have developed the software induced generator to measure the long-term sequence. We have considered the European benchmark of the standards called as EN 50160. All the disturbances are explained and generated with specific functional segments. We have used the several control commands before the generator to find the unified and final composite complex testing sequence.*

Keywords: Testing Procedure, Virtual Instrument, Labview Software Package, Power Quality Disturbances

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1. Introduction

Degradation of the electrical power quality (PQ), caused by increased using of the various power electronic components and powerful switching devices, directly affects on electrical power production process costs and reduces reliability of the customer electrical devices and equipment. In order to avoid such problems and to increase total energy efficiency level, electricity suppliers must provide appropriate quality level for the power distribution networks. For purpose of the customer protection, optimum PQ level is determined according to the relevant international quality standards and regulations [1,2]. Generally, PQ level is defined by acceptable interval values of the standardized quality parameters and some typical network disturbances. Relevant information necessary for assessment of the optimal quality level, can be provided by measurement, detailed statistical processing and analysis of the basic quality parameters at specific locations in some distribution network. Different classes of commercial instruments and equipment developed for measurement and software processing of the standard PQ parameters are available at the market. These instruments are developed to perform continuous monitoring of the power supply quality at selected locations in the power distribution networks. By measurement of the relevant quality parameters and by performing software supported statistical and diagnostic activities in the single or three-phase power distribution networks, these monitoring devices are capable to verify compliance of the measured quality parameter values with demands of the relevant PQ standards [3,4]. In order to satisfy specified level of the measurement accuracy and basic characteristics, devices for measurement of the PQ parameters must be followed by an appropriate metrological traceability chain. Metrological verification and testing of these devices must be performed in appropriate metrological laboratories. Reference instruments, such as voltage and current calibrators, are available in various functional and constructive variations. Such voltage and current calibrators are sources of the reference signals with high accuracy levels, which correspond to the secondary standards, laboratory and industrial standards in metrological traceability chain. Also, there are specially developed calibration instruments for specific types of the PQ meters, such as multifunctional calibrators Fluke 5520A and 6100B, supported by the special functions for PQ calibration.

Solution of the virtual instrument which will be presented in this paper, developed for automated detection, analysis and classification of the standard PQ disturbances, functionally is based on the LabVIEW virtual instrumentation software. This virtual instrument is capable to detect and analyze specific PQ disturbances as one of the seven possible outcomes: normal undisturbed signal waveforms, voltage swells, voltage sags, high-order signal harmonics, outage, voltage sag with highorder harmonics and swell with high-order signal harmonics.

2. Basic Characteristics of the Virtual Instrument

Concept of the virtual instrumentation is based on standard computers, hardware components for signal acquisition and graphical software packages specialized for presentation and software processing of the measurement results. Generally, basic functionality of the developed virtual instruments can be easily changed by simple correction of the software algorithm which controls execution of the measurement and acquisition process. LabVIEW software package enables development of the virtual instruments according to specific user requirements using predesigned functional blocks, elements and instrument front panels from software databases. Each virtual instrument includes two primary segments: basic front panel and software block oriented diagrams. Besides a number of the functional elements and blocks, functional block diagram of the virtual instrument in LabVIEW software environment, developed for detection, analysis and classification of the PQ disturbances, includes special MATLAB script and case structure which is capable to detect one of the seven possible outcomes related to previously mentioned disturbance categories. Front panel of the LabVIEW virtual instrument for disturbance detection and analysis is presented on Fig. 1. Final decisions about detected disturbance classes are indicated by numbers: 1 – undisturbed waveform, 2 – voltage swell, 3 – voltage sag, 4 – high-order voltage harmonics, 5 – voltage outage, 6 - sag with high-order harmonics and 7 – sweel with high-order voltage harmonics.

On Figure 1. are presented undisturbed voltage waveform and LabVIEW decision chart for graphical illustration of the final decision about detected PQ disturbance types in relation to the percentage amount of the disturbances. For this specific case virtual instrument for disturbance analysis is tested by normal undisturbed signal, so obviously final decision about detected PQ disturbance category is 1- undisturbed voltage waveform.

3. Description of the Virtual Instrument Testing Procedure

Procedure for testing of the described virtual instrument for analysis of the disturbances is performed using software based generator of the standard PQ disturbances. Solution of the PQ disturbance generator is based on the standard computer, D/A data acquisition board PCI NI 6713 and LabVIEW software package. Basic purpose of this generator is providing of the standard voltage waveforms, including some typical classes of the PQ disturbances, characteristic for real power distribution systems. Developed generator is capable to generate long-time and short-time test sequences, including some types of the PQ disturbances defined by European quality standard EN 50160, such as: slow voltage variations, voltage swells, voltage sags, spikes, interruptions, high-order harmonics, voltage swell with high-order harmonics and voltage sag with high-order signal harmonics [5]. Some basic functions of this PQ generator are:

- Definition of the nominal amplitude and frequency values,

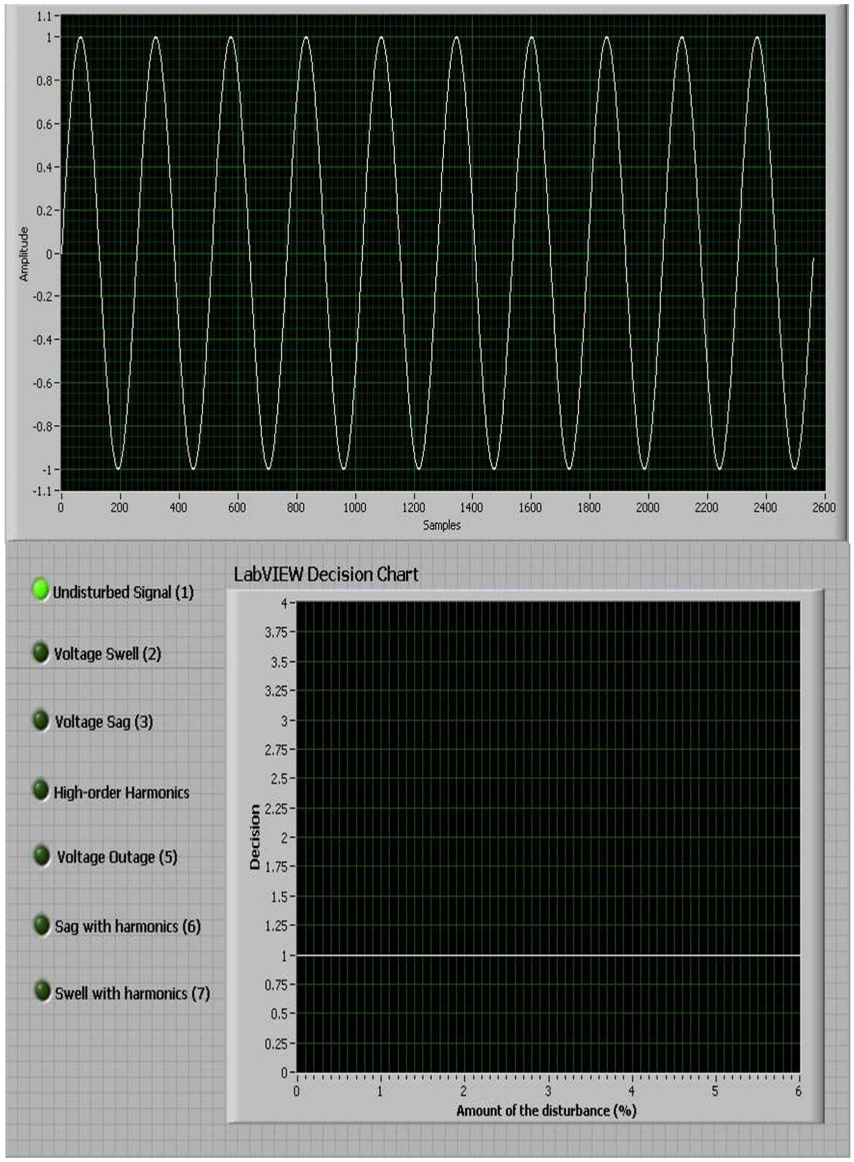


Figure 1. Front panel of the LabVIEW virtual instrument for graphical presentation of the voltage signal and decision chart

- Definition of the signal sample rate and duration of the final test sequence,

- Possibility for generation of the Gaussian noise,

- Variation of the nominal signal frequency value,

- Slow variation of the signal amplitude value with defined frequency of the variation,

- Definition of the signal DC offset,

- Definition of the voltage swells and sags,

- Definition of the high-order signal harmonics components with up to 11 individual defined harmonics. Fig.

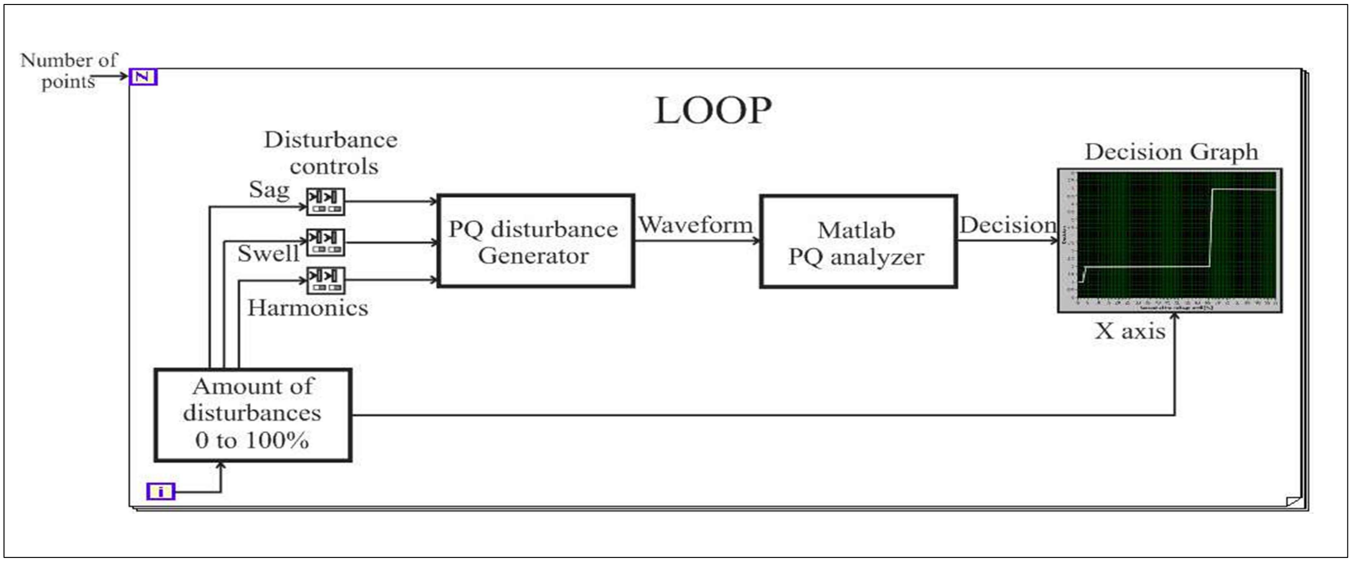


Figure 2. Functional block diagram of the procedure applied to testing of the virtual instrument for analysis of the PQ disturbances

In order to be more realistic, for particular disturbances is enabled definition of the signal rising and falling times, when disturbance change value from zero to defined maximum level as percentage value of the signal amplitude. For this purpose in LabVIEW software code is developed trapezoidal function as one common functional segment with time and amount of the disturbance variables in input cluster. For each individual disturbance can be separately defined start and stop times of this specific disturbance. By this software application is very easy to perform generation of the waveforms with various signal disturbances in serial combinations. Some additional types of the disturbances can be also generated as a subset of the developed generator. These characteristic disturbances are:

- Flicker as slow variation of the signal amplitude level,

- Pulse interference caused by lightning as high amount of the voltage swell,

- Voltage interruption defined as one type of the voltage sag,

- Voltage oscillation in short time caused by influence of the hugh-order voltage harmonic components.

Functional block diagram of the procedure applied to testing of the virtual instrument, developed for detection and analysis of the PQ disturbances, is presented on the Fig. 2. Testing procedure is consisting of four connected functional segments:

- Input section for control of the individual PQ disturbances (percentage amount from 0 to 100%),

- LabVIEW generator of the standard PQ disturbances,

- Analyzer of the PQ disturbances, originally developed in Matlab and implemented in LabVIEW software package,

- Chart for presentation of the decision about detected PQ disturbance types in relation to the percentage amount of the generated test disturbances.

Variation of the percentage amplitude level from 0 to 100% in input control segment can be enabled separately for each individual disturbance or at the same time for all types of the PQ disturbances. Generally, many different testing scenarios are possible, but for this specific purpose are analyzed some typical combinations of the signal disturbances. For example, on Fig. 3. is presented voltage test waveform with signal swell and correponding LabVIEW decision chart. Percentage values of the voltage swell are continuously changed from 0 – 100%. Final decision about detected disturbance is 2 – voltage swell.

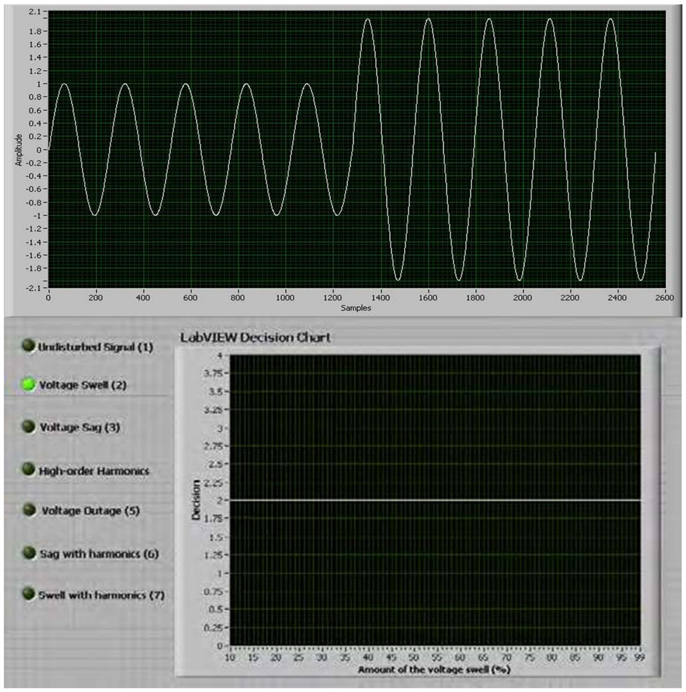
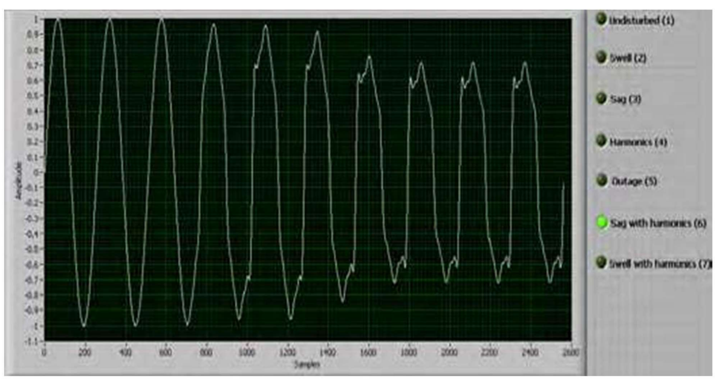
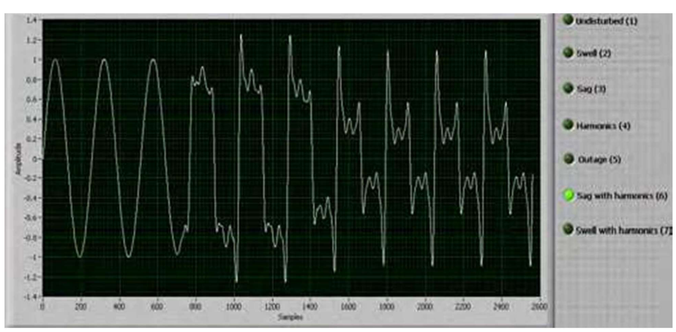


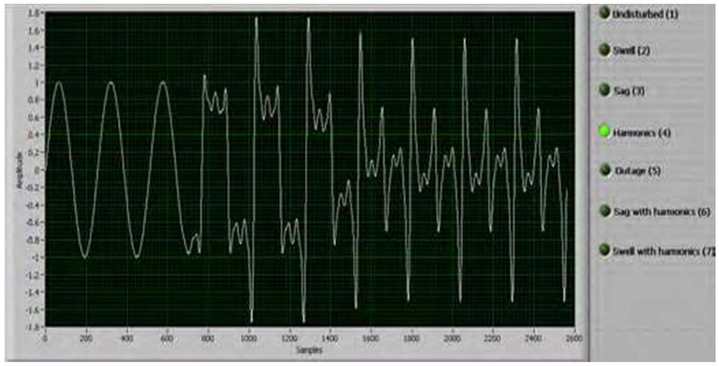
Figure 3. Voltage test waveform and LabVIEW decision chart (percentage level of the voltage swell 0 – 100 %)



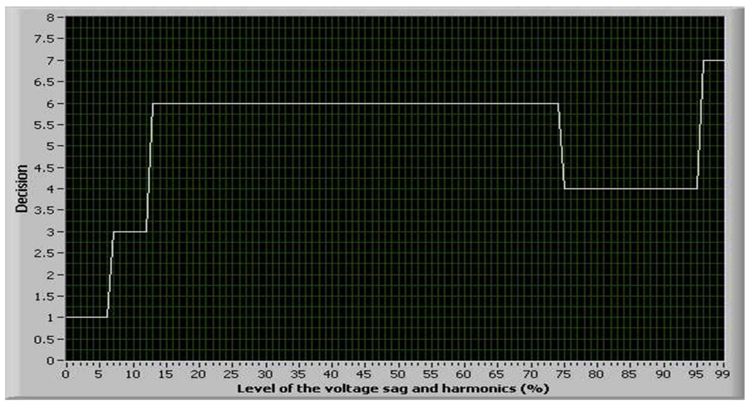
Disturbance level 25%



Disturbance level 60%



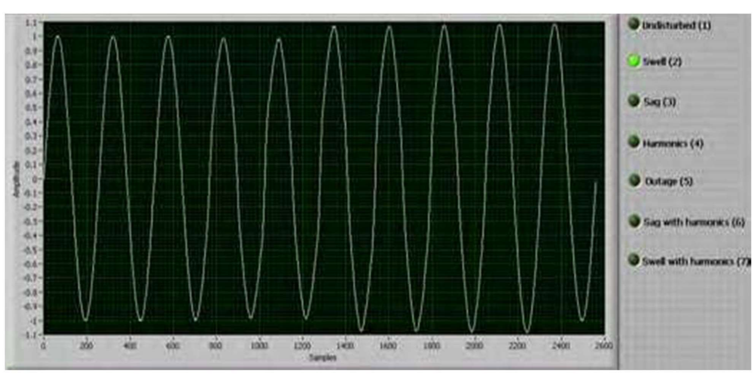
Disturbance level 90%



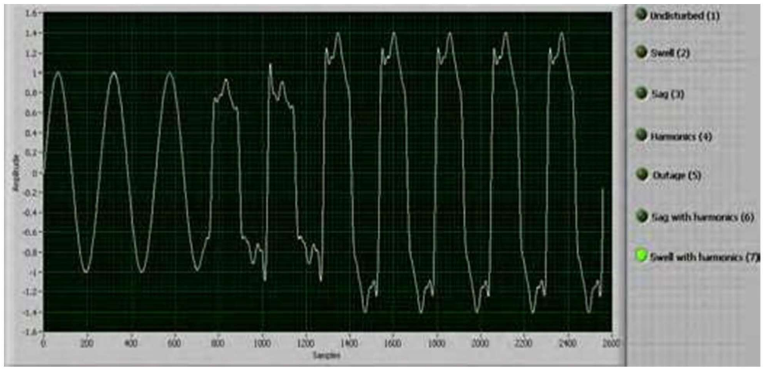
LabVIEW decision chart

Figure 4. Test waveforms and LabVIEW decision chart (percentage level of the voltage sag and high-order harmonics 0 – 100 %)

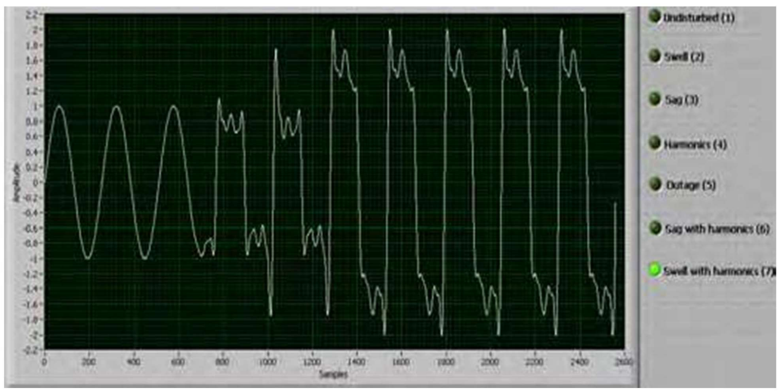
Generated voltage waveforms and corresponding LabVIEW decision chart regarding to combination of the voltage sag and high-order harmonics are presented on Fig. 4. On this figure are shown three different cases of the generated test waveform in relation to the percentage amount of the voltage sag and high-order harmonics (25%, 60% and 90% percentage levels of the disturbances). For 25% disturbance level decision about detected event is 6 – sag with harmonics. For 60% disturbance level decision is still 6, but for 90% disturbance level decision is changed to 4 – high-order harmonics. Finally, for 100% disturbance level decision is again changed to 7 – signal swell with harmonics, as is indicated on LabVIEW decision chart.



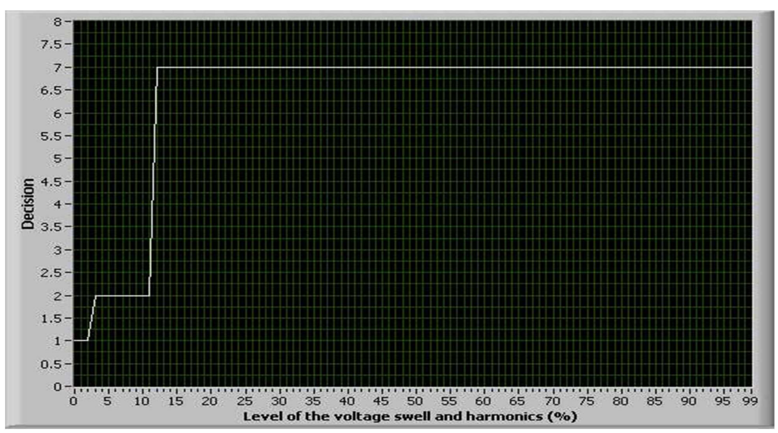
Disturbance level 10%



Disturbance level 50%



Disturbance level 90%



LabVIEW decision chart

Figure 5. Test waveforms and decision chart (percentage level of the voltage swell and high-order harmonics 0 – 100 %)

Final example of the voltage test waveform presented on the Fig. 5. includes combination of the voltage swell and certain level of the high-order signal harmonic components. For this specific example are also shown three different cases for 10%, 50% and 90% amplitude levels of the voltage swell and highorder voltage harmonics. For 10% disturbance level decision of the virtual instrument about detected disturbance category is 2 - voltage swell. Then, at some point decision is changed to 7, thus for 50% disturbance level, as well as for 90% level, final decision is constantly 7 – voltage swell with harmonics.

4. Conclusion

Procedure for testing of the virtual instrument, developed for detection and analysis of the standard PQ disturbances, is described in this paper. Functional basis of this procedure is provided using LabVIEW graphical software package. Virtual instrument is capable for detection of typical PQ disturbances, defined by European quality standard EN 50160, as one of the seven outcomes: normal undisturbed signal waveform, voltage swell, voltage sag, high-order signal harmonics, outage, sag with high-order signal harmonics and swell with high-order signal harmonics. Procedure for testing of this instrument is performed using software based generator of the standard PQ disturbances. Solution of the disturbance generator is based on the standard computer, data acquisition board and LabVIEW software package. Basic purpose of this generator is providing of the standard voltage test waveforms, including some typical classes of the signal disturbances, characteristic for real power distribution system. Each disturbance type can be individually defined and generated. Continuous variation of the percentage amplitude level from 0 to 100% in input control segment can be performed separately for each individual disturbance or at the same time for all categories of the disturbances. Generally, using this procedure are possible to perform many different testing scenarios, but for this specific purposes are analyzed some typical combinations of the various signal disturbances.

Acknowledgement

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